GROM #126

Epitaxial Growth of $(ZnO)_x(InN)_{1-x}$ Films by Magnetron Sputtering: Effects of surface polarity of ZnO substrates

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Summary We compared crystal qualities of sputter-deposited $(ZnO)_x(InN)_{1-x}$ (called, ZION hereinafter) on Zn-polar and O-polar ZnO substrates.
- The ZION film on O-polar substrate shows higher crystal quality than that on Zn-polar substrate.
- The Zn mobility on the substrate surfaces is critical to the quality of ZION film.

1. Introduction

ZION is the most promising material for exciton transistors.

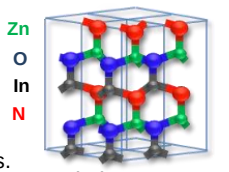
"ZION" is a pseudo-binary alloy of ZnO & InN. [1), 2)]

- Tunable band gaps in the entire visible spectrum
- High carrier mobility (>100 cm^2/Vsec @RT)
- High absorption coefficient (~10^5 cm^{-1})
- **High exciton binding energy** (30–60 meV)

- ZION is a quaternary material with complicated structure.
- Atomically flat surface is required to make exciton transistors.

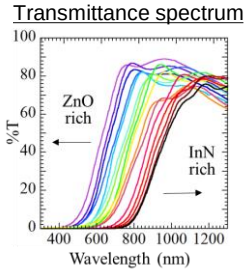
In order to improve the surface morphology of ZION films, we focused on the difference in surface polarity of the substrate, which is well known for ZnO thin films.[4)]

Crystal structure of ZON

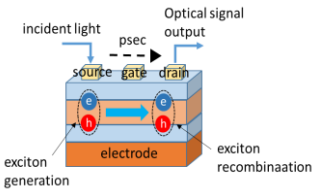


wultzite structure

Transmittance spectrum



Schematic of exciton transistor[3)]



1) N. Itagaki, *et al., Mater. Res. Express* **1** (2014) 036405.
2) K. Matsushima, *et al., Jpn. J. Appl. Phys.* **52** (2013) 11NM06
3) G. Grosso et al, *Nat. Photonics* **3** *(2009) 577-580.*
4) H. Kato, et al., *J. Crystal Growth*, ***265*** *(2004) 375–381.*

2. Purpose

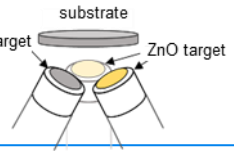
The surface polarity of the substrates might play an important role in adatom migration since it affects the sticking coefficient of adatoms.

To clarify effects of the polarity of the substrate on surface morphology of ZION films.

3. Experimental

All films were fabricated by RF magnetron sputtering

- Targets : ZnO, In
- Sputtering gas : Ar 30.2 sccm, N_2 24.0 sccm, O_2 1.8 sccm
- Total pressure : 0.50 Pa
- Deposition temperature (T_s) : 450°C
- Substrate : ZnO substrate



4. Results and Discussion

4.1 Crystal quality of ZION films

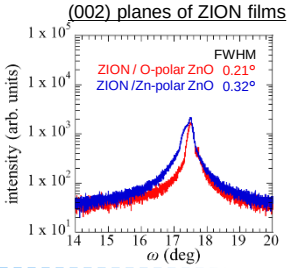
The ZION film on the O-polar surface has better out-of-plane alignment.

FWHM of the (002) plane rocking curve is reduced from 0.32° to 0.21° by fabricating on O-polar ZnO substrate.

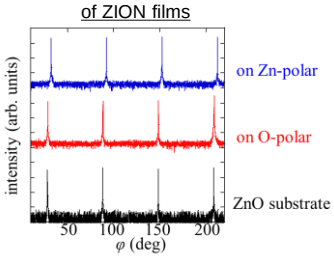
The ZION films have a six-fold symmetry.

⇒The ZION films grow epitaxially both on Zn-polar and on O-polar ZnO substrates.

X-ray rocking curves from (002) planes of ZION films



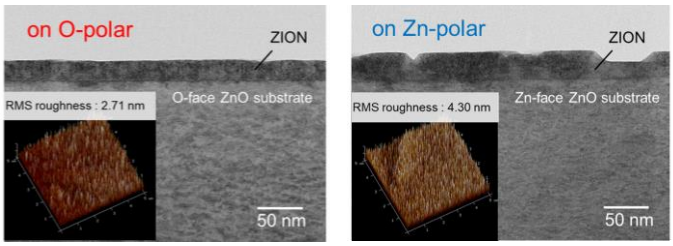
Phi scan from (101) planes of ZION films



4.2 Surface morphology of ZION films

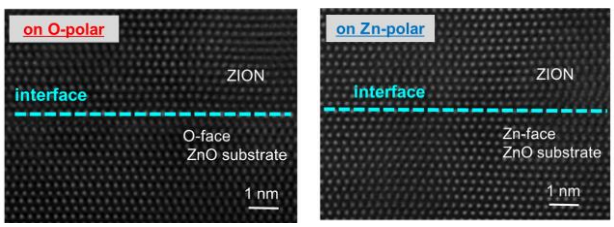
RMS roughness:
ZION on O-polar substrate 2.71 nm **<** **ZION on Zn-polar substrate** 4.30 nm

TEM images and AFM images of ZION films

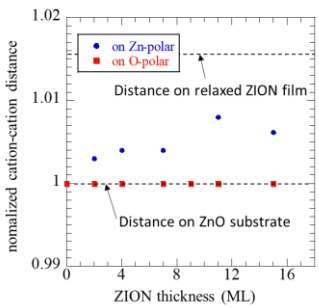


4.3 Lattice relaxation processes

High resolution TEM images of ZION films



Distances between Zn atoms as a function of ZION film thickness



- The ZION films were grown epitaxially on both ZnO substrates and has atomically sharp ZION/ZnO interface.
- ZION films grow coherently on O-polar ZnO substrates, whereas gradual lattice relaxation occurs on Zn-polar substrates.

We consider that these differences are brought by the differences in the adatom migration. O-polar surfaces provide smaller sticking coefficients and thus longer migration length of Zn/In atoms due to the smaller number of back bonds of Zn/In atoms on the surfaces.

5. Conclusions

We investigated effects of the polarity of the substrate on the crystal growth of ZION films for the first time.

- The ZION film on O-polar substrate has smoother surface than that on Zn-polar substrate.
- ZION films grow coherently on O-polar ZnO substrates, whereas gradual lattice relaxation occurs on Zn-polar substrates.

The Zn mobility on the substrate surfaces is critical to the quality of ZION film.

It was shown that even ZION, which is a quaternary material and has a complicated structure, has such atomically sharp interface.

Acknowledgements

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